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THE GEOLOGICAL STORY OF · JASPER NATIONAL PARK · CANADA

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THE GEOLOGICAL STORY OF JASPER PARK

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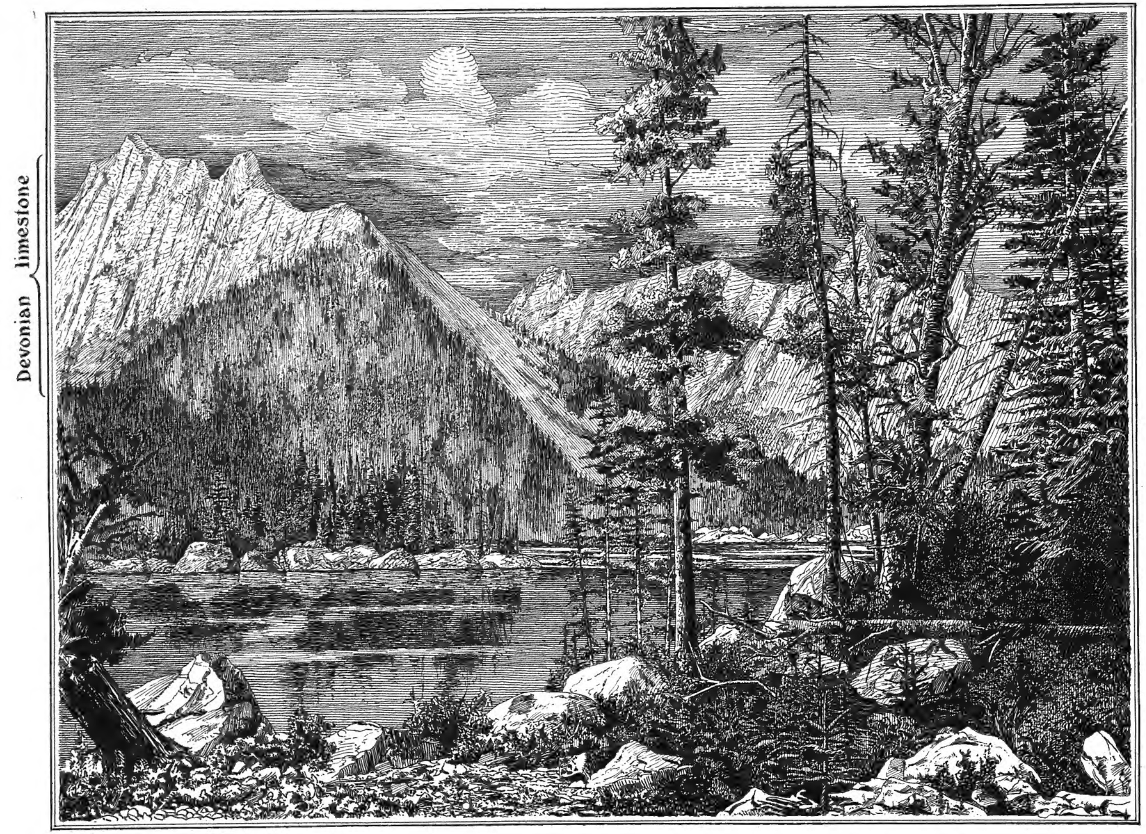

Devonian Limestone, Medicine Lake

THE GEOLOGICAL STORY OF JASPER PARK

ALBERTA, CANADA

by

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INTRODUCTION

ALONG the western border of the Great plains of Canada stretches a wide belt of ancient and shattered sea bottoms, crumpled in huge folds and set up on edge, known as the Rocky Mountains. Five thousand three hundred and eighty square miles of this great mountain system, lying on the eastern border of British Columbia and crossed by the 53rd parallel has been set aside by the Government as a National Park. Its centre lies about two hundred miles west of Edmonton. The traveller from the east first sees Jasper Park as a wall of steel grey limestone rising more than a mile above sea level. The Athabaska river cuts a notch in this wall through which the Canadian National railway enters the park. The railway passes out of the park on the west side through a pass which is bordered by peaks rising more than two miles above the distant Pacific. This is the famous Yellowhead pass, the lowest pass across the Rockies on the continent.

Near the centre of the park below the junction of the Athabaska and Miette rivers is located a little hamlet of attractive Swiss chalets in a broad valley of pine woods dotted with sky-blue lakes and rimmed with dove-grey mountains. This is Jasper, the starting point for automobile, horseback, and walking excursions to every part of the park.

The many fine trails of the park invite those who love walking to escape from the age of wheels and enjoy this ancient and invigorating exercise where automobiles are barred by mountain topography. On the mountain trails one may leave behind the softening influences of modern life and "live for the time a hardier, more natural life." Whether one chooses an altitudinal trail which leads above timber line or a longitudinal one which follows some charming valley, interesting geology and a rich variety of wild life await him. Those who prefer the speedier method of seeing the park by automobile will find nearly a hundred miles of excellent park highways giving access to such outstanding features as mount Edith Cavell, the Maligne canyon and Pyramid lake as well as the Athabaska valley for nearly 50 miles.

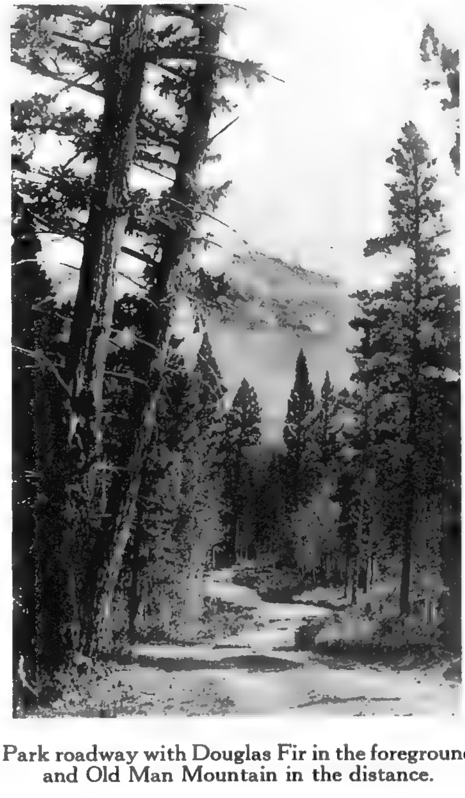
The written or human history of the park begins with the fur traders who first unfolded their blankets in the valley of the Upper Athabaska. The discovery of the Athabaska pass by David Thompson in 1811 made the Athabaska river an important highway for the fur trade between the British Columbia and the interior posts. This way went many of the gold seekers in the early sixties when the discovery of gold in the Cariboo started the first gold rush in western Canada. Many interesting and picturesque figures passed over this route across the mountains during the century which intervened between Thompson's pioneer journeys and the setting aside by the Government in 1907 of the Upper Athabaska basin as a National Park. One of these was the Scottish botanist, David Douglas, after whom the Douglas fir of the Rocky Mountains was named, who tramped through Athabaska valley with 50 pounds of seed, protected by an oilcloth, on his back in the spring of 1827. The genial Belgian missionary, Pierre Jean De Smet, arrived in 1846 at the Athabaska pass in a cariole and undertook there a month's fast to reduce his weight sufficiently to continue on snow-shoes his journey to the coast. Paul Kane, the artist, who passed through the Upper Athabaska valley in early winter, sketching the Indians whom he met, records that the November blasts transformed his long red beard into a huge icicle. The rather startling appearance of Kane's frozen whiskers had however some compensating advantage, since he relates that on one occasion it deterred three hostile Indians from attacking him.

How long the red skins whose dress and manners Kane has portrayed in his book had occupied the park before the coming of the fur traders we do not know.

We are not here concerned with the transformations wrought by man in making the mountains adjacent to the Upper Athabaska valley a unique playground and natural history preserve. The conversion of the old Athabaska trail with its carioles, snow-shoe journeys, and canoe brigades into part of a great trans-continental railway route has been described by others. It is the pre-human or geological history of Jasper Park which these pages will introduce to the reader.

The foundations of the Rockies were laid far back in the mists of time. Their geological history is recorded in the canyon walls and mountain sides where anyone who has learned the geological alphabet can read it. One may see in the West Indies limestones forming today from sea shells, coral reef sand and

calcareous ooze. In the Rocky Mountains limestones are displayed on a vast scale, miles in thickness, which were formed in the same way more than one hundred million years ago. These have preserved for us the fossil remains of the life which flourished in eons long past. This ancient life differs from that of today as much as the geography of its time contrasts with that of today. But both the life and the physical geography of today are the product of gradual changes occurring during the lapse of geologic ages of vast duration. During the long ages before man appeared in the world Nature recorded for him the history of the earth in the rocks. The winds and waves have been writing their story in sand dunes and ripple marks since the appearance of the first ocean. Animals have been leaving their tracks and their remains in the mud on lake and seashore ever since the dawn of life. Even the "worms that crawled upon the half-finished surface of our planet, have left memorials of their passage enduring and indelible."



Park roadway with Douglas Fir in the foreground and Old Man Mountain in the distance.

It is but little more than two hundred years since men began to puzzle out the alphabet in which this pre-human history of the world is written. As early as 1688 the mathematician and natural philosopher, Robert Hooke, shrewdly observed that rotten shells are "more certain tokens of antiquity than coins or medals since the best of these may be counterfeited."

The great interplay of organic and inorganic factors, which are changing the geography of today into the very different geography of tomorrow, can perhaps nowhere be better seen than in Jasper Park.

The mountains of Jasper Park may be regarded as one of the great archives of the continent. Only a geologist's hammer is required to unlock their secrets. One may travel for a thousand miles across the plains east of the Rocky Mountains and see little more than the skin of the earth. There one cannot go very far back of the geography of today. Inside the portals of the Rocky Mountains, however, pre-human geography is recorded on every mountain side. A hundred sea bottoms of immense antiquity have been broken up and displayed to the enquiring eye. The great sheets of limestone, sandstone and shales, which represent these old sea bottoms, preserve the shells, bones and fossil plants of some of the most remote periods of geological history. These old sea bottom records form a great stone book, miles in aggregate thickness, whose pages are open to those who wish to know the great story of the past and how our present day geography came into existence.

Geology puts into our hands a telescope with which we can in the words of Tyndall "see backward through the night of antiquity and discern the forces which have been in operation upon the earth's surface."

"Ere the lion roared
Or the eagle soared."

Roche Miette.

HOW THE MOUNTAINS BEGAN

In an old Hindoo story Ammi says to his son, "Bring me a fruit of that tree and break it open.... What is there?" The son said.... "Some small seeds." "Break one of them and what do you see?" "Nothing, my lord." "My child," said Ammi, "where you see nothing there dwells a mighty tree."

If the reader will for a moment transport himself in imagination backwards in time many millions of years he will observe where now the Rockies stretch away from the confines of Jasper Park towards the north and south for hundreds of miles, only an ocean. In it he will see as little of the mountains which there await their birth as Ammi's son saw the "mighty tree" which dwelt in the seed. The mountains are present in this ancient sea as horizontal beds of sand, calcareous ooze and mud. If this backward journey in time is repeated a million years later a low-lying land will be found where the Cretaceous sea had been. This land rose slowly above the sea which it had displaced. Probably in its most rapid period of elevation it rose no more than a foot in a century.

Whistlers Mountain from Jasper Park Lodge.

The development of streams and the beginnings of erosion which must follow the exposure of any part of sea bottom to the air and the rain were coincident with the elevation above the sea of this old land. And so the beginnings of the mountains date from the time when the new land was first exposed to the winds and the rains. The margins of the new land became the battle ground of the tides, the waves and the rivers. The sea sought to advance over the newly arisen land. But the shifting, branching streams which spread their sand, gravel and mud deposits along the swampy coast repelled the onslaughts of the sea and slowly land was added along the eastern and western margins of the new land. Deep seated earth forces continued to lift higher this new sea border land and as time passed the warping of the earth's crust elevated still higher the sea-formed sediments from which the Rocky Mountains were ultimately carved.

MOUNTAIN SCULPTURE

> "Water nourishes vegetation; it clothes the low-lands with green and the mountains with snow. It sculptures the rocks and excavates the valleys, in *most cases* acting mainly through the soft rain, though our harder rocks are still grooved by the ice-chisel of by-gone ages"
>
> —Sir John Lubbock

The stroller along mountain streams who is given to reflective moods finds, like the melancholy Jacques, tongues in trees, books in the running brooks, sermons in stones, and good in everything. If he can understand the great part which the tiny brooks play in mountain sculpture, he may get the feeling of interest in mountain rills which prompted Thoreau to write: "I am accustomed to regard the smallest brook with as much interest, for the time being, as if it were the Orinoco or Mississippi, and when a tributary rill empties into it, it is like the confluence of famous rivers I have read of—Its constant murmuring would quiet the passions of mankind forever."

The small streams are constantly active in carving the gorges and steep-walled mountain valleys. It is, too, the function of the rivers to bear to the sea the sand and other debris produced by their incessant sawing and grinding action.

Every brook and river tells in its own way how it has helped to carve the valleys which have set in high relief the towering peaks and majestic ranges of the Rocky Mountains. Mountain streams produce boulders, gravel, sand, and rock flour, as efficiently under natural conditions as they grind wheat flour

Maligne Lake.

when harnessed to a mill. Big streams like the Rocky river show through their clear waters only well rounded boulders and gravel of rounded pebbles which have travelled far from the parent ledge. If one listens beside this swift stream to the subdued roar of its waters he will hear the sharp click, click of the smaller boulders and pebbles as they clash and grind against each other, each contact helping to round up and reduce whatever angles may remain. If one follows to its source some mountain brook he will see that the pieces of rock near its head are all nearly as angular as when they were pried off the ledges and cliffs by the frost.

The Athabaska river, which receives nearly all the drainage of Jasper Park, is always turbid or milky-coloured with rock flour which a hundred glaciers have ground for its waters. The finest of this sediment is deposited on the bottom of Athabaska lake, 500 miles northeast of the park, through which the river passes on its way to the Arctic sea. No glaciers of note debouch

into the Rocky river and other valleys of the eastern ranges so that they take toll of the mountain slopes only in spring and early summer when the spring snows are flooding all the streams and carrying tiny rock fragments from nearly all the mountain slopes to the valley streams. In the valleys occupied by the glaciers the etching of the rock by the ice and the boulders embedded in it as they very slowly move over the valley floor affords a continuous summer supply of finely pulverized rocks to the streams flowing from them. This etching of the glacial ice at the head of a valley frequently transforms the head of a "V" shaped valley into a great bowl-shaped depression called a *cirque*.

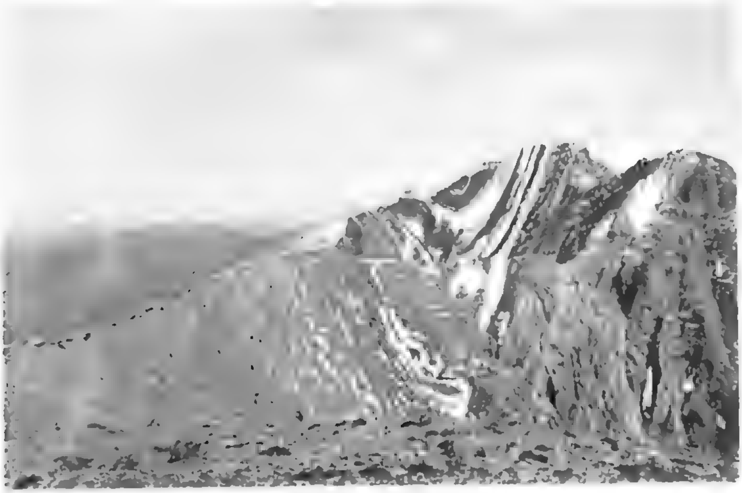
The efficiency of streams in cutting down their valleys is proportional to their grade, so that all streams tend to cut their valleys to a uniform grade. The rate of degradation or wear by erosion of a rock is dependent on its hardness and its solubility. Differential or unequal erosion therefore occurs in any set of rocks which is not entirely uniform in hardness and composition. Erosion begins as soon as a land mass is raised above the sea and it ends only when the mass has been returned to the sea. Emergence of a new land above sea level is followed immediately by the development of a drainage system. The courses of streams are determined at the time of emergence by accidents of slope and the location of troughs or folds in the rocks. In early youth streams cut for themselves steep walled canyons. These in time widen by the decay of their walls into "V" shaped valleys. These again with the passage of time become metamorphosed into wide valleys with sluggish streams. The major streams extend their branches to every part of a land as it comes to geological maturity. The incessant nibbling of thousands of tiny streams at every part of a great land mass as the eons pass leaves the harder rocks in high relief. So the lofty ranges and high peaks of the Rockies have come into existence through the incessant efforts of the rivers to carry their sea-born sediments back to the oceans whence they came. Valleys have developed where the action of water has been most effective, either through the presence of relatively soft rock or lines of structural weakness. The wide north-south trending valley in which the coal mines are located at Pocahontas and Bedson is a good example of a valley carved in soft rocks. Hard limestone ranges rise three thousand feet above this valley of soft shales and interbedded sandstone.

When one looks at the fantastic cap of Roche Miette or the majestic peak of mount Edith Cavell he may ask, as Tyndall does in his "Hours of Exercise in the Alps," "Who chiselled these mighty and picturesque masses out of a mere protuberance of the earth?" If he does he will find as Tyndall did the answer to hand "Ever young, ever mighty—with the vigour of a thousand worlds still within him—the real sculptor was even then climbing up the eastern sky. It was he who raised aloft the waters which cut out these ravines; it was he who planted the glaciers on the mountain slopes, thus giving gravity a plow to open out the valleys; and it is he who, acting through the ages will finally lay low those mighty monuments, rolling them gradually seaward, sowing the seeds of continents to be; so that the people of an older earth may see mould spread, and corn wave over the hidden rocks which at this moment bear the weight of the Jungfrau."

GEOLOGICAL STRUCTURE

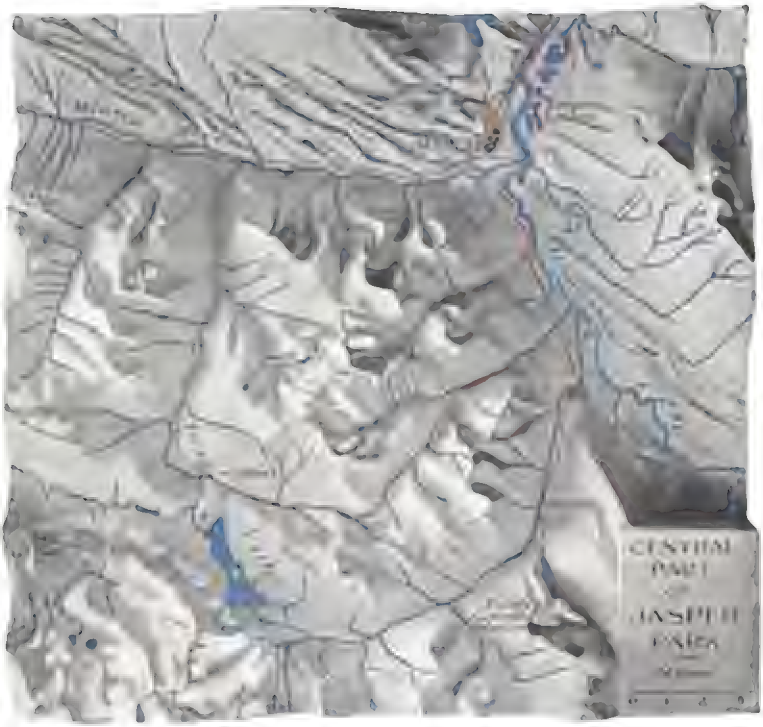
One who is unfamiliar with the slow cumulative effect of the work of pressure, water, and frost may find it difficult to understand the origin of the structures shown by the limestone and quartzite mountain ranges composed of beds tilted at every conceivable angle. The great "V" shaped folds set in the crest of Roche a Perdrix at the eastern threshold of the park will lead the visitor to ask how and when were such structures impressed on rocks nearly as hard and unyielding as steel. Just inside the eastern park entrance the huge elbow folds shown by the north face of enigmatic Roche Miette challenge him to guess the riddle of their history. The beautiful limestone arch at the lower end of the Rocky River gorge, set like a rainbow across the stream, the vertical strata of Fiddle Creek gorge, and a hundred other strikingly displayed examples of mountain structure, put question marks all over the mountain landscape for those not well versed in the genealogy of the mountains. They may be reminded of Hesiod's observation that "to him who commands time nothing is impossible." The geologist's command of time runs to many millions of years. Hence the development of the great folds, troughs, and arches of the Rocky Mountain ranges from beds which were once horizontal presents no serious difficulties to him. They bring him face to face, however, with forces of almost inconceivable magnitude acting through a vast period of time.

Ruskin observes that mountains are the beginning and the end of all natural scenery. Certainly they are the paradise of the structural geologist. In the Rockies the bed rock has been stripped of the earthy mantle which conceals many of its secrets in the lowlands. The naked mountain cliffs disclose every detail of the gigantic fold and trough structures which mountain



Roche Perdrix near the eastern entrance to Jasper Park.

building forces have impressed upon them. The upward arches of these folds are called by geologists anticlines and the troughs between synclines. The expansion of the ice on northern lakes sometimes produces arches three or four feet in height which are comparable in a very small way with the huge wrinkles which have developed in the Rocky Mountain zone from the adjustment of stresses in the earth's crust. The rocks of Jasper Park which were originally flat lying beds of limestone, shale and quartzite have been crumpled into a series of great folds. The terrific lateral and upward pressure responsible for these was continued till the folds broke along several lines and slipped upwards at various high angles across one another along planes known as faults. These great pressure folds and the associated faults have a northwest and southeast trend diverging about



Central part of Jasper Park as it is today. Light coloured patches represent glaciers, all of which are more than a mile above sea level.

45 degrees from due north. The direction of the Rocky Mountain ranges has been fixed by the original folding of the rocks although the original troughs are often responsible for mountain range crests and the arches for the valleys. There is perhaps no more impressive scenery in the Athabaska valley than the Palisades, with a maximum height of 2,500 feet which rise as a sheer wall for six miles along the west side of the valley southeast of Snaring river. Here the Athabaska is deflected from its normal north and northeasterly course across the trend of the ranges by a great fault which brings up at the foot of the Ramparts' wall the Cambrian rocks.

Nearly all the larger streams except the Miette and Athabaska have directions determined by the trend of the mountain ranges which in the eastern half of the park follow the general northwest and southeastward trend of the ranges. These mountain ranges are the remnants of the harder beds of the great folds and troughs which were impressed on the rocks during and after their upheaval from the sea by titanic pressures exerted chiefly from the west. Perhaps the best example in the park of a structural valley is the wide valley lying east of Miette and Bosche ranges. At the base of Miette range the Cambrian rocks are in contact with Cretaceous rocks along a fault plain over which the older rocks have slid upwards several thousand feet. A profound fault bounds the eastern side of this valley, the two having preserved from the destructive erosion attending mountain sculpture a belt of coal-bearing rocks which must, in pre-mountain times, have extended far to the west of this valley.

The eastern side of the front range of the Rocky Mountains is limited by a great fault plane along which the old Palaeozoic rocks [1] were broken, then thrust upward and over the younger Mesozoic [2] formations with their coal seams. This fault plane is admirably exposed in the mountain face just back of Brulé station. East of this great fault the Palaeozoic rocks do not again appear at the surface, west of central Manitoba. The crumbling and breaking of the rocks which produced the Rocky Mountains did not extend very far eastward of the foothills which flank the mountains for a few miles east of the park. Beyond these, across Alberta and Saskatchewan to the borders

[1] The Palaeozoic rocks form "the first legible volume of the earth's history".

[2] See Diagrammatic section of the earth's crust.

of the Precambrian rocks in eastern Manitoba, the Palaeozoic and Mesozoic rocks lie as they were formed in horizontal sheets, except for a few very gentle undulations.

In the southwestern portion of the park the same fold and trough structures prevail which have produced the serrated ranges of the eastern part; but quartzites are dominant rocks west of Jasper as limestones to develop into numerous individual

Gorge of Two Valley Creek, Medicine Lake Road.

peaks which do not display so well the continuity of the long folds as do the limestone ranges of the eastern part of the park.

Some of the quartzites and the associated silicious shales in the central part of the park display beautifully developed joint-plane structures. These are well shown on the eastern side of the Old Fort ridge near the Athabaska bridge between Jasper and the Lodge. Here two sets of vertical joint planes, at right angles to each other, cut the sediments into rectangular columns. These structures greatly facilitate the work of frost in breaking down cliffs. Immediately east of this bridge the cliffs exhibit well the original bedding, or the layers formed as horizontal beds when the rocks were deposited as water-laid sediments, which now stand in a vertical position as a result of mountain building forces. Superposed on the bedding planes near the river are cleavage planes at a sharp angle to the bedding. The latter as well as the zones of fractured thin limestone bands in the same beds are among the products of the stresses which resulted from the mountain-building forces.

UNDERGROUND WATER AND MINERAL SPRINGS

The geological work of water is not entirely confined to the surface of the rocks. A part of the rain enters the joints, which everywhere traverse the rocks to considerable depths. Along fault planes and other structural features surface waters may penetrate to great depths where they sometimes take on the high temperature of the interior of the earth and then reach the surface as warm or hot springs. Where the depth reached is not sufficient to produce thermal waters the absorption of carbon dioxide frequently greatly increases the solvent power of underground as compared with surface water. This often results in highly mineralized waters and in underground erosion along subsurface joint plains, which may carve subterranean stream channels of considerable size. This has occurred at the lower end of Medicine lake where a considerable volume of water leaves the lake by an invisible subterranean channel. The activities of underground waters include the abstraction of various minerals from rocks at different levels and their re-deposition elsewhere along the courses traversed. From such activities mineral veins may be formed. Mineral springs result where such waters emerge from an underground course which traverses beds with minerals readily soluble in carbonated waters.

Mineral springs, as commonly understood by the general public, include those whose waters are or may be used in the treatment of disease. There are in the park several springs with water highly charged with the minerals which characterize the waters at well known health resorts. Both hot and cold mineral springs occur in the park. One of the most accessible of these is a cold sulphur spring with a strong flow of water which breaks from a cliff of Devonian limestone in which the strata stand in a nearly vertical position. This spring is at the side of the Jasper and Pocahontas highway 14 miles from Jasper. Another mineral spring about half-a-mile northeast of the above is located 200 yards southeast of the highway. Sheep and deer trails radiating from this spring indicate its high repute among these creatures. An analysis of the water of this spring by Mr. E. A. Thompson of the Department of Mines follows:—

ANALYSIS

Constituents		Parts per million
Sulphuric Acid	(SO_4)	288 0
Bicarbonic Acid	(HCO_3)	287·0
Carbonic Acid	(CO_2)	5 3
Hydrogen sulphide	(H_2S)	104·0
Chlorine	(Cl)	274 0
Silica	(SiO_2)	0 5
Ferric oxide and alumina	(Fe_2O_3) (Al_2O_3)	0 7
Calcium	(Ca)	121 0
Magnesium	(Mg)	49 0
Sodium	(Na)	200 0
Potassium	(K)	trace
		1,329·5

HYPOTHETICAL COMBINATION

Sodium Chloride	(NaCL)	452 0
Potassium Chloride	(KCl)	trace
Sodium Sulphate	(Na_2SO_4)	68·0
Magnesium sulphate	$(MgSO_4)$	242·0
Calcium Sulphate	$(CaSO_4)$	69·0
Calcium bicarbonate	$(Ca(HCO_3)_2$	388·0
Silica	(SiO_2)	0·5
Iron and Alumina and	(Fe_2O_3) (Al_2O_3)	0·7
Hydrogen Sulphide	(H_2S)	104·0
Carbonic Acid—free	(CO_2)	5·3
		1,329·5

The analysis shows this spring to fall in the saline-sulphurated group of mineral waters and to belong to the same class of waters as the well known French Lick and West Baden springs of Indiana. The magnesium sulphate content indicates that this water represents the aperient or mildly purgative type.

The springs which are best known for their therapeutic effects are the hot sulphur springs which break from the mountain wall 12 miles southeast of Pocahontas. These springs are of different temperatures up to 120° F. Sulphates of lime and magnesia form the major part of the dissolved solids, being represented respectively by 22.68 and 77.28 grains per gallon. (Summ. Rept. Geol. Surv. Can. for 1910, p. 167). The springs issue from the limestones near the centre of a broken anticline where the strata stand at a high angle. The hot baths at these springs have been utilized for medicinal purposes for many years. Those who visit them, whether sick or well, will doubtless receive benefit if they observe the injunction which was placed above the baths of Antonius at Rome: "Curae vacuus hunc adeas locum ut morborum vacuus abire queas." Come to this place free from care that you may leave it free from disease."

GEOLOGICAL CHRONOLOGY

Geologists are sometimes asked what fossils are good for. Those who first practised the art of writing were probably asked a similar question about the utility of that art. Both fossils and writing have one important use in common. They furnish precise information about the past. While written history covers only the recent past, the fossil record goes far back toward the beginnings of life on the earth.

A history which has for its stage the whole earth and for its subject all past life and its slow development from the lowest forms into man himself can not take a subordinate position to anything which has ever been written. Paraphrasing the praise which one of the old poets gives to the "loftiness of thought" of Homer we may say:—

> Read earth history once and you can read no more,
> For all books else appear so mean and poor.

In many different countries the mountains have been considered the dwelling place of the gods. If we no longer expect

to find Jupiter on Mount Olympus, we find there and on a host of other cloud shrouded mountain summits the records of creation—the creation which has been in progress for untold millions of years. Perhaps these venerable records in stone, recorded by fossils, are as worthy of veneration as were the mountain dwelling gods of the ancients.

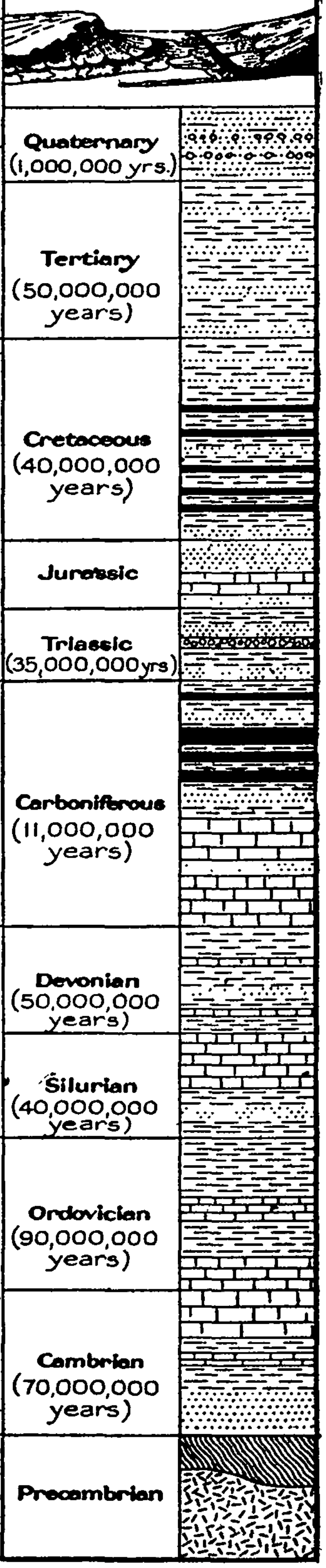
The major divisions of geological time and their sequence are indicated in the following table. The presence or absence in Jasper Park of rocks representing the several eras is indicated in the right hand column.

Palæozoic Era

Cambrian.—There are probably a few people like the vivacious young lady, who when asked if she was interested in history, replied that she preferred to let bye-gones be bye-gones. But those who in any degree understand how the past, present and future are bound together in the wonderful unfolding of life must find intensely interesting the stages of life development which are recorded in the Palæozoic rocks.

The mountain sculpture which everywhere meets the eye in the park speaks eloquently and convincingly of the immense period of time which the brooks and rivers required for its production. But the carving of the mountains required only a small fraction of the vast time interval involved in the formation of the rocks from which the mountains are made.

The earliest rocks in which the remains of life are found abundantly belong to the Cambrian system. These rocks were formed in the early part of the Palæozoic era before animals with a backbone had appeared in the world. The rocks on which the Palæozoic systems rest are known as the Precambrian rocks. Near the western border of the park, along the Miette valley in the vicinity of Yellow Head pass, the Precambrian series, which is vastly older than the Cambrian, is exposed. These most ancient rocks belong to the same rock series which constitutes the Canadian shield of the northeastern quarter of the continent. They are considerably metamorphosed showing garnet and other minerals characteristic of rocks which have been subjected to high temperatures. The Cambrian rocks which overlie them increase in thickness beyond the park limits toward the west and have at mount Robson a thickness of more than twelve thousand feet.



ERA	CHARACTERISTIC LIFE	DIAGRAMMATIC SECTION OF THE EARTH'S CRUST	Synopsis of Life	Occurrence in Jasper Park
CENOZOIC	AGE OF MAN	Quaternary (1,000,000 yrs.)	Animals and plants of modern types including man.	Present
	AGE OF MAMMALS AND MODERN PLANTS	Tertiary (50,000,000 years)	Possible first appearance of man. Rise and development of highest orders of plants.	Not present
MESOZOIC	AGE OF REPTILES	Cretaceous (40,000,000 years)	Rise and culmination of huge land reptiles (dinosaurs), of shell fish with complexly partitioned coiled shells (ammonites), and of great flying reptiles. First appearance (in Jurassic) of birds and mammals; of cycads, an order of palmlike plants (in Triassic); and of angiospermous plants, among which are palms and hardwood trees (in Cretaceous).	Present
		Jurassic		Present
		Triassic (35,000,000 yrs)		Present
PALÆOZOIC	AGE OF AMPHIBIANS AND LYCOPODS (MOSS-LIKE TREES)	Carboniferous (11,000,000 years)	Dominance of club mosses (lycopods) and plants of horsetail and fern types. Primitive flowering plants and earliest cone-bearing trees. Beginnings of backboned land animals (land vertebrates). Insects, Animals with nautilus-like coiled shells (ammonites) and sharks abundant.	Present
	AGE OF FISHES	Devonian (50,000,000 years)	Shellfish (Mollusks) abundant. First known land plants, and large fishes dominant.	Present
		Silurian (40,000,000 years)	Rise and culmination of the "sea lillies" or crinoids. Reef building corals and cephalopods prominent.	Not Present
	AGE OF HIGHER (SHELLED) INVERTEBRATES	Ordovician (90,000,000 years)	Shell-forming sea animals, especially cephalopods and mollusk-like brachiopods, abundant. Culmination of the trilobites. First trace of insect life.	Not Present
		Cambrian (70,000,000 years)	Trilobites and brachiopods most characteristic animals. Seaweeds (Algæ) abundant. Land animals unknown.	Present
	AGE OF PRIMITIVE INVERTEBRATES AND ALGÆ	Precambrian	First life that has left distinct record. Algæ, brachiopods and Crustaceans present. No fossils found in lower part.	Present

The oldest rocks known in the eastern half of the park outcrop near the eastern entrance. High up the slopes of Roche Miette, a mile and a half southwest of Pocahontas, occur beds of impure limestone crowded with moulds of large salt crystals showing very plainly the cubes and concave hopper-shaped crystals in which common salt crystallizes. On the same mountain, in strata a little older, we find trilobites which date these rocks in the Cambrian era. Thus we find more than 4,000 feet above sea level both physical and organic evidence that some of the older rocks of Roche Miette were formed in a sea which was salty enough at times for the salt to form crystals. The trilobites which have been extinct for millions of years, represent a group of crustaceans known only in association with marine fossils. The testimony of the rocks is therefore unequivocal in showing that the wierdly bent and twisted older strata of Roche Miette represent sediments which slowly accumulated on the sea bottom in Cambrian times when the trilobites were the aristocrats of creation. Land plants were not yet in existence. Brachiopods of rather primitive types and some other types of mollusca comprise, with the trilobites, the bulk of the life of the seas during the long ages when the oldest sediments which we find in the eastern park ranges were being laid down on the sea bottom.

Another and later chapter in the early Palæozoic history of the park is laid bare along the base of the great 3,500 foot wall called the Palisades. A brook cuts a deep notch in this wall seven miles north of Jasper. In the lowest rock exposure in this stream the limestone contains an abundance of small brachiopods and other fossils representing the Ozarkian fauna, which indicates a position in the time scale near the border line of the Cambrian and Ordovician eras.

It is important to understand that in nearly every region, chapters of the geological history are missing or preserved only in a very fragmentary way. This is true in Jasper Park where the rocks of two geological systems which should follow the Ozarkian fauna are missing. These are the Ordovician and Silurian systems. Such missing records can usually be supplied from some other region where marine conditions were not interrupted and the preservation of fossils was continuous.

Devonian.—The vast period of time bridged in passing from the Cambrian to the Devonian limestones which immediately succeed them is indicated by the fact that the rich molluscan

fauna found in the Devonian rocks contains not a single genus or species in common with the Cambrian faunas. In this part of the Rocky Mountains land conditions appear to have prevailed during Ordovician and Silurian times, so that the marine life of these periods is not represented in the park.

Somewhere in *Gil Blas* there is a story of two Castilian boys who chanced to notice while resting by a spring one day the half obliterated words on a stone: "Here is confined the soul of the licentiate Peter Garcias." One of the boys thought the mystical words a joke, but the other, who took them more seriously, soon uncovered with his knife a purse containing 200 ducats and a card with the Latin message: "Be thou mine heir, who hast had wit enough to discover the sense of the inscription, and make a better use than I have done of my money." Anyone who will turn aside from the highway to Maligne lake and enter one of the deep narrow canyons which head up toward the mysterious looking figure called the Old Man of the Mountains may find certain oddly curved lines on the canyon walls. These obscure symbols will also lead the finder to a discovery and a reward if he has the wit and industry of the Castilian youth for they are sections of sea shells. A heavy hammer is all that is required to resurrect here beautifully preserved sea shells of many different kinds. The majority of these shells are brachiopods which lived during the Devonian epoch many million years ago. The whole mountain east of the Medicine Lake road and trail is a veritable cemetery of these Devonian shells. The canyon walls carved by the rushing streams within them look ancient, but their time-scarred walls compare with the age of these shells as yesterday does to a thousand years. The shells take us back to the bright blue sunlit seas where the shell fish lived and died for untold thousands of years. Their accumulated shells form a large share of the mass of many of the mountain ranges in the eastern half of the park.

Carboniferous.—The trail between Medicine lake and Maligne lake crosses, near the south end of the former, from rocks of Devonian to those of Carboniferous age. The ravines and mountain slopes south of Medicine lake show a succession of shale and limestone formations, some of which abound in fossils. At the big bend in the Maligne river fossil corals are beautifully exposed at the roadside. The light grey limestone ledges which form the mountain slopes east of the north end of Maligne lake are also composed in large measure of Carboniferous fossils.

It is in the Carboniferous rocks that crinoids become common in this region. They are abundantly represented in the limestones by small cartwheel shaped discs with a pit or hole in the centre. These little discs are sections of a long column, having often the diameter of a lead pencil, which was attached by roots to the sea bottom and supported a somewhat pear-shaped body bearing branching arms. The plant-like appearance of this curious animal is recognized in the name "stone lily" which is often applied to it. These stone lilies flourished on the sea bottom when the earth was several million years younger. The rarity of perfect specimens of crinoids is well known to collectors. It is recorded in an old German book dated in 1774 that the Emperor of Germany once offered a hundred thalers for a good specimen of "stone lily." There are only a few localities in North America where specimens in a good state of preservation are common. In one of these, Burlington, Iowa, three hundred and fifty species have been found.

Mesozoic Era

Various factors have conspired to make some pages of the early and middle Mesozoic geological record meagre and obscure in Jasper Park. But we know from the fossil remains preserved elsewhere that the early Mesozoic was the time when some of the most important groups of modern life had their beginnings. A sombre, flowerless vegetation spread over the land and the Age of Reptiles dawned. The progenitor of modern birds appeared in the Mesozoic times as a feathered creature with a long, many-jointed tail and jaws with teeth instead of the horny beak of modern birds. It was in the early Mesozoic days that many of the great reptiles acquired the art of flying. Some of these dragons of the air had a wing spread of 15 to 20 feet. During early Triassic time small mammals appeared in the world. In the Connecticut valley the Triassic sandstone abounds with tracks of the early dinosaurs. But in Jasper Park fossil land animals are unknown and marine fossils are rare. In the seas the beautiful, coiled shells called ammonites appeared and remained the dominant forms of marine life to the end of Cretaceous time when they vanished from the earth as completely as did the long-tailed Mesozoic birds.

Two widely distinct types of rocks represent early Mesozoic time in Jasper Park. One of these is the black shale formation, with interpolated chert and limestone bands, which is well

exposed along Rocky river below Jacques creek and along the lower part of the Jacques Creek trail. The western facies constitutes a great series of quartzites and grey shales with occasional interpolated beds of barren, impure limestones. The contact of this series and the Palæozoic limestone is exposed on the mountain slopes about a mile northeast of the game warden's cabin at Maligne lake. All of the mountain ranges from Maligne lake westward across the Shovel pass and on to the Tonquin valley on the western border of the park appear to be composed of this great series of quartzites and shales, which have a thickness of not less than 10,000 feet. These rocks, from which most of the mountains in the southwest third of the park have been carved, represent sediments laid down near a subsiding shore line along the eastern border of a land mass which occupied much of western British Columbia in early Mesozoic times.

Modern types of flowering plants and insects including beetles, ants, and bees make their first appearance in Cretaceous times.

In Jasper Park the known Cretaceous fossils include only plants. These occur in the shales near the coal seams at Pocahontas, and on the opposite side of the Athabaska river near Bedson. Fossil plants may be observed along the trail to the Punchbowl falls and at the old mine dump at Pocahontas.

The rich dinosaur fauna found along the Red Deer river, some two hundred miles southeast of the park, must have included Jasper Park within its range, although it has not been found there. While these huge creatures browsed no doubt on some of the plants which we find as fossils near Pocahontas, they left their bones in the shallow lakes where flooded rivers of that time carried them. Their extinction and disappearance from the American fauna was the most significant event of late Mesozoic times.

The abrupt disappearance of the dinosaurs near the end of Cretaceous time may have been the result of the drying up of the marshes in or near which many of them lived. Perhaps they found themselves in the predicament which the frogs of the ancient fable feared when they heard it rumoured that the Sun would take a wife and complained to Jove that:

> "Even now one Sun too much is found,
> And dries up all the pools around
> Till we thy creatures perish here;
> But oh, how dreadfully severe,
> Should he at length be made a sire,
> And propagate a race of fire."

In the case of the dinosaurs however it was not the sun but the rising of the Rocky Mountains which lead to the disappearance of their low marshy environment of late Cretaceous times.

The Rocky Mountains in Tertiary Times

The Tertiary era was a time of great importance in Rocky Mountain history. In its fossils we find the beginnings of our present fauna and flora. In early Tertiary times the region of the Rocky Mountains was near sea level. The birth time of the Rockies began in early Tertiary days, when a wide bel of land, newly risen from the sea, became exposed to erosion. As this western part of the continent rose through middle and late Tertiary times the great valley of the Athabaska and its tributary streams had their grades steepened and their erosive power correspondingly increased. It was during this time that the mountains of Jasper Park took shape and were carved to resemble in some degree the mountains we know today.

Most of the Cretaceous beasts which we know best—the dinosaurs—had vanished from the earth, probably as a result of geographical changes. The remnants of the old Cretaceous fauna and flora were during this modernizing epoch slowly changing into something resembling our present day animals and plants. In the Yellowstone National Park, at Amethyst mount may be seen the remains of fifteen forest growths one above the other buried in lava. From this and other localities, such as Florissant, Colorado, remnants of Tertiary lake deposits show the first appearance of such modern trees as the magnolia, oak, tulip, sassafras and ash.

About the Tertiary insects of the Rocky Mountains we also know something from the famous locality at Florissant, Colorado. Here the hordes of insects which lived in Tertiary times about the shores of a small lake were brought into the lake and covered by showers of volcanic ash before they could be eaten by fish or destroyed by decay. One of the interesting bits of ancient insect history revealed by the Florissant deposits relates to the tsetse fly. A near relative of the insect which causes the "sleeping sickness" of Africa was found in these old Tertiary deposits. Localities where ancient insect life has been preserved in perfection are almost as rare as diamond mines. But we have fortunately such localities as the Baltic Sea coast where thousands of insects long extinct have been trapped in the exuded gum of coniferous trees. Here in the amber of the Eocene we find the

bee, and many other insects as well, "locked up hermetically in its gum-like tomb—an embalmed corpse in a crystal coffin." Other fortunately preserved bits of Tertiary history appear to justify us in believing that the Tertiary was also the time of origin of most of the higher mammalian families "from mice to men." But the recent discoveries made in the Gobi desert in Asia show that some of the mammalian families have their beginnings in Cretaceous times. Concerning this newly discovered link in the chain of mammalian evolution Gregory writes as follows:—

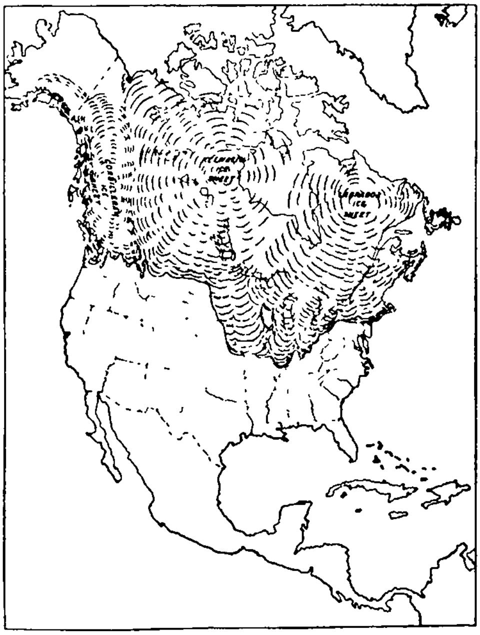
"The swarming dinosaurs of the Cretaceous age in Mongolia probably paid little attention to the 'wee timorous beasties' with pointed snouts and furry coats that scampered around under their feet. With no one to warn them of the dangers of letting in a horde of immigrants that would eventually crowd them off the earth, the dinosaurs went on playing the game of life in the good old way and the immigrants did the same. For many hundreds of thousands of years the dinosaurs muddled through, but near the close of the Cretaceous age their doom was sealed and they disappeared from the earth in Mongolia as well as elsewhere. Thus the mighty were put down and the meek inherited the earth."

"Numerous reasons have been alleged for this momentous event. Some have suggested that the little mammals broke into the dinosaurs' eggs and ate the contents. Others hold that in the long run the mammals came through because of their superior equipment for resisting severe changes in temperature; because of their improved locomotor apparatus, better brains and far less wasteful methods of reproduction."

In late Middle or Upper Tertiary times a land connection between North America and Asia, across Behring strait, probably came into existence which permitted the Mongolian mammalian fauna, which had its roots back in Cretaceous days, to migrate to America. In British Columbia elements of the Asiatic and American faunas doubtless mingled and developed a southern Canadian fauna, which must have taken on the characteristics of a mountain fauna as the mountains grew. We actually know about this fauna, however, only through remnants of it found elsewhere. The elevation of the northern part of the continent in late Tertiary times and the consequent refrigeration and increase of precipitation brought to an end the mild climatic conditions of the Tertiary and introduced the Glacial epoch. The sediments and fossils of Tertiary times which may have accumulated in Jasper Park were swept out and destroyed by the ice.

The Quaternary Period

The Coming of the Glaciers.—A great climatic change which affected all of the northern hemisphere closed the Tertiary epoch. "The winter snowfall begins to exceed the summer melting. Slowly gathering ice-fields form, deepen and creep toward the south, driving all life before the advance of the



Continental Ice Cap.

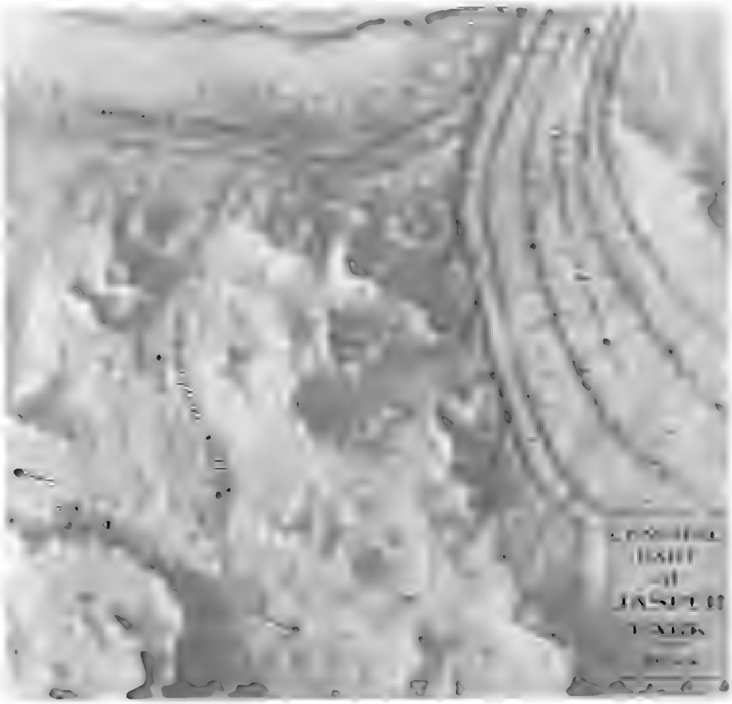
frozen desert. Warmer intervals come, marked by the retreat of the ice, but the glacier each time recovers its lost ground and advances farther into more temperate latitudes until it reaches to Long Island, and the Alleghany, Ohio, and Missouri rivers. The northern half of the continent is given over to a reign of ice. The ice margin advances and recedes, and upon each retreat leaves behind it belts of moraines, soil mantles of

stony till, rock ledges polished and scored. The elephant and mastodon and others of the race of mammals—warm blooded, clothed with hair, and adaptable to changing conditions—follow quickly northward each recession of the ice." The present climate of Arctic Canada is very mild compared with the chill which gripped the whole continent of North America as far south as the Ohio and Missouri rivers for a hundred thousand years or more. A vast continental ice-cap covered Canada and the northern States. The deep mountain valleys of Jasper Park furnish abundant evidence that this part of the Rocky Mountains shared in the general continental glaciation. Nearly every mountain valley in the park shows masses of boulder clay from 500 to 1,000 feet or more above the present valley bottoms. These very old remnants of ground moraines indicate the former presence of valley glaciers which during the time of maximum continental glaciation filled the broad Athabaska and all its tributary valleys, nearly if not quite to the tops of the mountain ranges. The presence of an abundance of quartzite boulders in the eastern north and south valleys suggests that the ice may have covered even the mountain ranges in the central and eastern parts of the park since all known parent ledges of the quartzite which might have supplied these lie in the western or central parts of the park. The valley of Moosehorn creek and its southern continuation south of Pocahontas displays in the drift a great abundance of quartzite boulders which must have been derived from the ranges twenty-five miles or more to the west. Similar boulders are present everywhere in the valley of Rocky river. Boulders and pebbles of metamorphosed rock occur on the slopes of Roche Miette which came from some more remote locality to the west or southwest and cannot be accounted for without a nearly complete submergence by the ice of the Miette and other ranges which lie between the easternmost valleys and the quartzite area of the central and southwestern parts of the park.

The continental ice sheet came, retired and returned at least three times, the glacial geologists tell us. Presumably the great valley glaciers of the Jasper Park area waxed and waned in unison with these great continental transformations from land to ice and back again. The evidence of great physical transformations within the park after the first coming and retreat of the huge valley glaciers which filled the Athabaska and all its tributary valleys is conclusive. Finally:

"The ice draws back again, pausing in arctic latitudes. But this time there soon appears from the west a race of savage men. The Human Period has dawned in America. Then like a flash in the swift flight of years another race is seen, pouring in ships across the eastern sea. The genii of nature bow as slaves and at their command there rises from earth the apparition of the cities of civilized men."

Post Glacial Conditions.—When the great valley glaciers finally withdrew to the heads of the mountain valleys they were no longer the deep "V" shaped valleys of Tertiary times. Morainal deposits had filled many of the smaller ancient valleys



Central part of Jasper Park as it appeared during the Ice Age when more than 2000 feet of glacier ice covered the site of Jasper Village and the Lodge.

some hundreds of feet. Every trace of the age long accumulation of Tertiary soils had been swept from the valleys by the ice and the bottoms of the valleys had been widened by glacial scour. After the withdrawal of the Athabaska glacier to the upper part of the Athabaska valley a long deep lake gleamed for a time where the glacier had been. It occupied the Athabaska and its tributary valleys within the mountains, up to a level of 400 feet or more above the present Athabaska river. During its early stage great deltas of gravel and sand were built in it about the mouths of streams entering it. The thick gravel and sand deposit behind the town of Jasper represents a delta deposit in this Pleistocene lake formed by the Miette river deposits. At a later period in the history of this lake, when the various mountain valley glaciers had retreated far up their valleys, deposition of gravel and boulders on the front of these deltas ceased. A veneer of fine textured lake silts was then laid down over the frontal margins of the deltas. These silts contain an abundance of lime and occasional thin bands of marl. One species of fresh-water shell still living in the park lakes occurs in these silts at an elevation of 350 feet above the river at Pocahontas. The bands of marl in the silt indicate that this high level lake was coincident with a climate having warm summers, for marl forms only in lakes which are exposed to a fairly high summer temperature. The disappearance of this long deep lake, which may be called Miette lake from the river which built into it at Jasper an extensive delta, probably resulted either from the cutting down of some old morainal barriers left across the Athabaska valley at the junction of the mountain glaciers and the continental ice sheet outside the eastern border of the park, or from the melting of the continental glacier. Miette lake probably belongs to the same interval which produced the great expanse of lake Agassiz in Manitoba, lakes Bonneville and Lahontin in the Rocky Mountains of Utah and Nevada and many other large lakes which characterized the North American landscape during the Champlain period. Jasper and Brulé lakes are the largest remnants of this lake of Champlain times which had a length of 60 miles or more.

Existing Glaciers.—Hamerton speaks of a walk on a great glacier as one of the "four new experiences for which no description ever adequately prepares us," so extraordinary is it "that one might be in another planet." Any one of the rivers of ice which embroider the great Columbian ice-field will convince

Central part of Jasper Park as it appeared several thousand years ago, after the continental ice sheet had largely melted when a deep lake filled most of the Upper Athabaska Valley.

the eye which is new to this kind of landscape of the futility of a written description as a means of giving any conception of the majesty of a glacier. Splendid examples of Rocky Mountain glaciers may be seen around the southern part of Maligne lake, in the Tonquin valley, and the upper valley of the Whirlpool.

Boulder clay on road to Mt. Edith Cavell Glacier.

Scott glacier near the southwestern border of the park is considered one of the most spectacular of Rocky Mountain glaciers. The majestic, snow covered pyramid of mount Columbia, second among Rocky Mountain peaks only to mount Robson

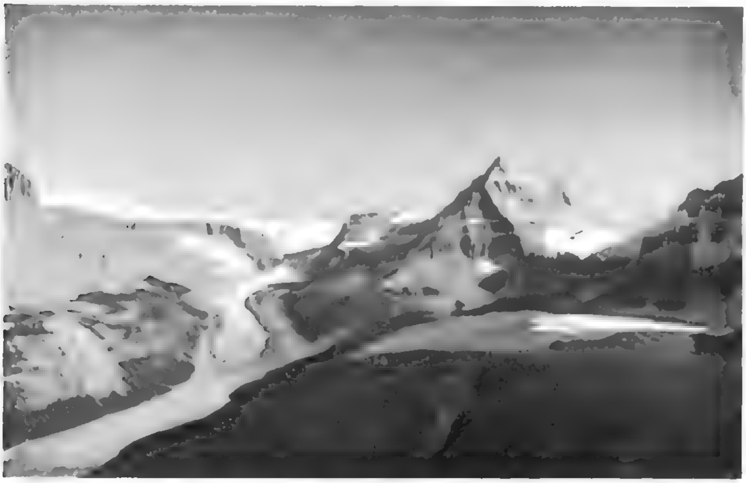
Athabaska Glacier, 1917. Photo by Topographical Survey.

in elevation, with its abundant glaciers is shown in the photograph on page 36. Many of the large glaciers near the Columbia ice-field can be reached only by a five or six day trip on horseback, but the beautiful Cavell glacier with its moraines, ice towers and pinnacles, lies at the end of a one hour automobile drive which commands one of the finest river and mountain views in the Rocky Mountains.

The great valley glaciers of the Ice age are represented by remnants which now end mostly above 5,500 or 6,000 feet, near the heads of the smaller mountain valleys. Though relatively small the geological work of these glaciers is far from insignificant. The huge rock walls which some of them have built around their sides and ends from stone blocks often approximate 100 feet in height. The Swiss name *moraine* is applied to these boulder ridges and the various forms of rock waste carried by the glacier. Considerable areas of some of the glaciers are covered by rock fragments. Small stones absorb heat quickly from the sun's rays and sink slightly into the ice. Stones too large to become heated through in a day protect the ice from the sun and become elevated on pedestals of ice forming the stone tables of the glaciers. Small streams frequently flow for a short distance over the glacier surface till they fall into a crevasse or crack in the ice. Such a stream may reach the bottom of the glacier by a vertical well or shaft in the ice which is called a *moulin*. The tongue or snout is the lower end of a glacier. A small piece of light coloured rock buried in the ice a few inches will sometimes reflect the sun's rays upward and cause the formation of a tube or well-shaped depression above it.

All of the glaciers which have been visited in Jasper Park show by a series of abandoned moraines outside the ice margin that a considerable retreat of the ice has taken place within a rather recent period. In front of the north glacier at Bastion peak in the Tonquin valley, a frontal moraine extending from near the present ice margin to Moat lake, nearly a mile, is divided into two sharply contrasted sections. One is a wall-like moraine of quartzite blocks a few rods from the ice front, rising in places 100 feet or more above the lower section, which is a broad irregular belt of blocks. The blocks of the latter are closely covered with lichens giving it a dark grey colour while the former is nearly free of lichen and as a result much lighter in colour. Although the rocks in both sections are of the same

material the colour contrast is sharp enough to be seen at a considerable distance. The lichen-free moraine is of too recent origin for these plants to have had time to establish themselves on it.



Head of Athabaska River, Columbia Glacier on left, Mt. Columbia on right, 1919. Photo by Topographical Survey.

The glaciers furnish by their retreat or advance an accurate index of present-day climatic trends. Since everyone takes an interest in the weather all observations bearing on glacial expansion or contraction should command general interest. As a basis for future observations on the position of the ice front at Mount Edith Cavell glacier, the distance from the large boulder shown on page 38 to the edge of the ice was measured along a line fixed by the boulder and a flag pole on the large moraine to the right of the tea house.[1] This distance on July 17, 1927, was 322 feet, 6 inches. On August 22, 1927, this distance had increased to 342 feet. The series of abandoned moraines composed of fresh rock, the outermost of which are more than 500 feet from the ice, appear to indicate a considerable recent retreat of the ice front. The forested moraine, which is only a few yards outside the outermost bare rock moraine, shows a composition which is altogether different from the moraines inside

[1]Remeasurement of this line by Prof. E. L. Perry in 1929 showed a retreat of 92 feet 6 inches in two years.

it, the latter being composed solely of sand, gravel and quartzite rocks while the outer moraine includes a considerable amount of glacial clay. This difference suggests that formation of the forested moraine occurred during an advance of the ice after a period when the glacier had almost completely vanished and left an ice-free valley long enough to develop a soil, which on the return of the ice furnished material for a moraine quite different from those which were made later and are still in process of formation.

The glacier at mount Unwin on the west side of Maligne lake shows, like the other glaciers seen, evidences of recent retreat in abandoned moraines, parts of which are nearly a quarter of a mile from the glacier front.

View of the Ramparts across the Tonquin Valley.

Observations begun by the Vaux brothers and Miss Mary Vaux (Mrs. C. D. Walcott)—which have been made on five glaciers south of Jasper Park by measuring for a series of years the distance of the ice front from marked rocks, have shown all but one to be retreating. For one of these, the Yoho glacier, the retreat for 12 years was at the rate of 33 feet per annum. The single glacier which showed an advance is heavily covered with rocks which have probably protected it from melting. A. O. Wheeler[1] has shown that the average annual retreat of

[1] Can. Alpine Journal, Vol. 13, pp. 158-159, 1923.

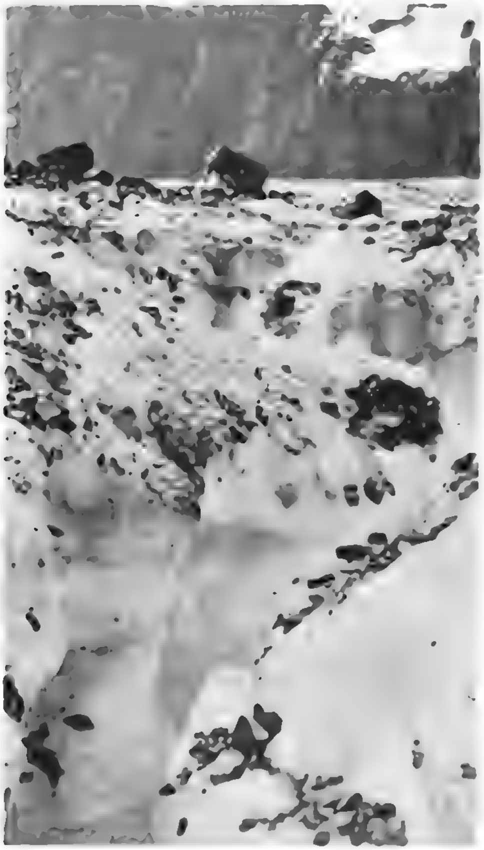
Robson glacier from 1911 to 1922 was 261 feet at one observation point and 22.1 feet at another. Both Dr. G. M. Dawson and R. G. McConnell [2] have expressed the opinion that all of the glaciers examined by them in British Columbia were either

Morainal belt from which Mt. Edith Cavell Glacier has withdrawn. The boulder at the side of man was 322 feet 6 inches from front of glacier on July 17, 1927.

stationary or retreating. The rate of retreat of the Rocky Mountain glaciers which have been studied is rather insignificant compared to the rapid retreat of glaciers in the mount Fairweather region in Alaska. W. Osgood Field [3] reports that one glacier in that area has completely vanished, leaving a fiord in its place, and that another has almost disappeared in the last three years. He finds that the front of the Johns Hopkins glacier has retreated 7 miles since the summer of 1921. J. C. Russell,[4] who summarized his own observations and those of others on Alaskan and other North American glaciers, found that the great Malispina glacier of Alaska had retreated 5 or 6 miles within the past 100 years. He concluded that the glaciers of North America everywhere are retreating. Professor Dufor [5] reached a similar conclusion concerning the existing glaciers of Europe and Asia.

[2] Am. Geol., Vol. 9, p. 326, 1892.
[3] Bulletin of Appalachian Club, Vol. 20, p. 468, 1926.
[4] Am. Geol., Vol. 9, pp. 329-330, 1892.
[5] Bull. Soc. Vand Sc. Nat., Vol. 17, pp. 422-425, 1881.

No one who has seen the recently abandoned moraines of the Jasper Park glaciers is likely to doubt that their evidence falls in line with that of glaciers elsewhere in America in pointing toward a secular climatic change representing a diminished snow-fall cr a warmer climate or both.



Stream channel cut in surface of Mt. Edith Cavell Glacier.

Three or four hypotheses have been developed by geologists to explain the cause of the glacial period. A considerable increase in the size of the land areas in the northern part of the globe such as would result from a notable elevation of the

Angel Glacier, Mt. Edith Cavell.

northern part of the continent would cause a general lowering of the temperature in that part of the earth. If accompanied by increased precipitation such a general continental elevation should result in an ice cap of the continental type. Another possible factor in developing glacial climates is variation in the composition of the air. Carbon dioxide and water vapour are the two essential constituents of the blanket which keeps the earth warm by absorbing the heat which would otherwise be radiated into space. A slight increase in the carbon dioxide in the air would therefore give the whole earth a tropical or subtropical climate like that of the Carboniferous age, while the removal from the atmosphere of all the carbon dioxide would cause the temperature of the earth's surface to drop 37° F., according to Arrhenius, and lock the whole world in Arctic ice. A compensating balance, however, which is maintained by the passage of carbon dioxide from the sea to the air, as the sup-

ply in the latter is used up by rocks and plants, prevents any sudden great change in the volume of carbon dioxide in the air. But the locking up of vast quantities of carbon dioxide in coal beds and limestone formations must tend to alter greatly the proportion of this gas in the air in different geological periods and modify climates accordingly.

LAKES, GORGES AND OTHER POST GLACIAL FEATURES

Lakes.—Lakes are the most evanescent of geographical features. Some types of lakes, like the playas of the South West, have only an ephemeral existence. They appear with the rains of early spring and vanish in the heat of summer.

While the lakes of the mountains do not belong to the seasonal type, they are short lived in the geological sense. A lake which has a prospective lifetime of a hundred thousand years must be considered a very temporary feature when compared with the mountain peaks which towered above the valleys for ages before the coming of the Continental Ice Sheet and the great valley glaciers, which made the lakes possible. Lakes are almost as responsive to climatic conditions as were the glaciers which prepared the ground for their birth.

The retreat of the great valley glaciers left in the valleys, which before their advent were evenly graded, a succession of moraines. These, here and there, blocked the river valleys, thus substituting lakes for the rivers which had carved the old valleys. The processes of sedimentation began as soon as the lakes were formed—the deposition on their bottoms of silt and organic remains which must ultimately result in their extinction. In Jasper lake, through which the Athabaska river flows, this process is already far advanced. The deposition of a few more feet of silt will transform most of its bottom into a low sand plain.

Maligne lake, a glacier bordered lake about 15 miles long, which lies about 5,000 feet above sea level, is being rapidly silted up by glacial streams from opposite sides of the lake. Within two or three centuries the two deltas at the narrows will unite and divide Maligne into two lakes. Several more centuries will be required for the glacial rock flour to completely fill the basin south of the narrows and convert it into a level sand plain covered with the Arctic cotton plant.

In many of the small lakes of the lower valleys lake extinction is in progress, which is in no way connected with the silting up of lake bottoms by glacial waters. Calcium carbonate, which forms a white soft mud, called marl, is accumulating on the bottoms of most of the small lakes near Jasper Lodge. Various small lakes along the Athabaska river have been nearly filled with this soft cream-coloured mud. The more elevated lakes do not supply the high temperature essential to the growth of the aquatic plants which extract from the water much of the lime which goes into the making of marl. The warmer zone of the lower valleys is also an essential to the high evaporation required to bring lake water to or near the supersaturation point for calcium carbonate which is essential to marl deposition. Elevation thus controls in a definite way the kind of sediments which are laid down on the lake bottoms and the kind of rocks which they will form in the remote future.

The Maligne River valley is occupied by two large lakes, Maligne lake at the head of the valley and Medicine lake a few miles lower down. Maligne river, a large clear stream, and a good sized brook from the east empty into the head of Medicine lake, but there is no visible outflow at the lower end of the lake valley. Medicine lake occupies a limestone basin and huge limestone blocks are scattered about the lower end of the basin. The outflow of the lake is through a subterranean channel. A considerable part of the water from this subsurface channel emerges gradually below the lake and becomes the lower Maligne river, which a few miles below Medicine lake has carved the deep Maligne gorge. At the lower end of the gorge a very large spring issues from the vertical west wall, which apparently represents the terminus of one branch of the subterranean Medicine Lake river. The subsurface outlet of this lake fails to take up the inflow as rapidly as it enters during periods of large precipitation so that the lake surface often rises several feet during rainy weather and slowly subsides in dry seasons.

Beavers sometimes permanently raise the level of small lakes by dam building. This has occurred at Beaver lake east of the head of Medicine lake, where many trees recently killed standing about the margin of the lake indicate the higher level to which the beavers have raised this lake.

Colour of Lakes.—The charm of the Jasper lakes depends in large degree on the rich variety of colours which their waters

display. They may be thought of as the eyes of the mountains reflecting every passing mood of the sky into which they constantly look. They show a range of blue, green and indigo shades which makes them rival the colour contrasts of the tropical and subtropical seas. Each lake has its own individual colour tone which is sometimes nearly the same, but often

Cavell Lake and Mountain.

strikingly different from that of a neighbouring lake. John Tyndall[1] has described in his "Voyage to Algeria" twelve different colour shades which he recognized at different points in the sea in the vicinity of the western end of the Mediterranean. He records crossing a marine current boundary, where "standing at the bow of the ship a bottle could be filled with blue water while at the same moment a bottle cast from the stern could be filled with green water." All of the colour shades which Tyndall observed near Gibraltar and others may be seen along the thirty-mile drive from Jasper Lodge to Pocahontas where the highway follows the ash grey thread of the Athabaska river charged with rock flour from glacial streams. Scores of small lakes are distributed along this stream like beads on a necklace. Some are directly connected with the river while others lead an independent existence but each has its own individual colour shade. Even Jasper, the large lake through which the river directly flows, softens the grey of the river to something like a straw-colour on a bright day. From this rather dull shade there is displayed in the chain of Athabaska lakes every degree of green and blue up to the deep ultra marine blue of Edith lake near the Lodge. Cavell lake, which is located below Edith Cavell glacier and receives the turbid subglacial stream of that glacier, shows a peculiar pea-green colour. Enthusiastic alpinists assert that no words can describe the gloriously coloured tarns and lakelets of the higher valleys and passes.

The marvellous shades of green, blue and violet which the lakes display with a wealth of examples can be more easily explained than adequately described. The colour of lake water is closely correlated with the quantity and kind of fine suspended matter which it holds and with the character of the bottom. The solar rays on penetrating water are rapidly absorbed or extinguished. In a lake of great depth and uniform density which contained no suspended matter whatever, complete extinction of the solar beam would occur. Beyond a reflected glimmer from the surface none of the sunlight which reached the lake would return to the eye and the colour of the lake would approximate that of ink. Lakes with water completely devoid of suspended matter, however, do not exist. Suspended matter, usually of both organic and inorganic origin, is always present in some quantity, and the innumerable fine particles of such matter reflect the light entering the lake back

[1] Fragments of Science, p. 127.

to the surface and give colour to the lake water corresponding to the quantity and the reflecting power of the bottom. Experimental work on sea water has shown that bright and clear green colour is associated with an abundance of suspended fine particles and black indigo or deep indigo with much less suspended

The Punch Bowl.

matter. Small quantities of suspended sediments play much the same role in giving colour to lakes that dust fills in colouring the sunsets. It is to dust in the air that we must ascribe the blue of the sky and much of the glory of the sunset.

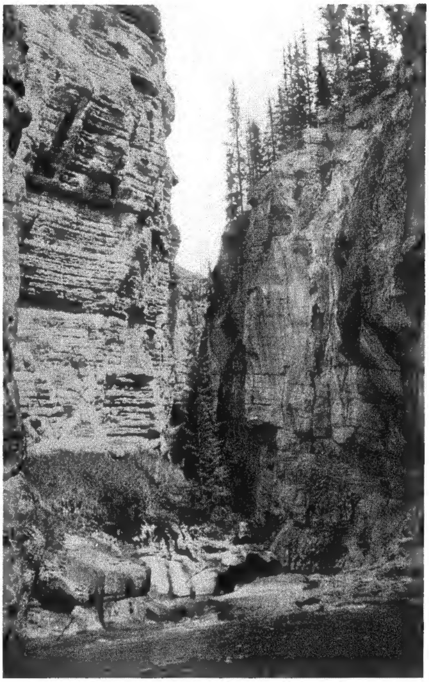
Many lakes like those of the Tonquin valley and some which are connected with the Athabaska river have suspended in their waters small quantities of glacial rock flour which reflects to the surface of the lake the blue green or violet rays. Others like Annette lake have white marl bottoms which reflect the light rays through the water and produce the cobalt blue which characterizes some lakes.

Gorges.—Gorges like lakes represent youthful features of the landscape. With the passage of time the vertical or overhanging walls of a gorge became metamorphosed into "V" shaped walls. These sloping walls in turn are slowly gnawed by the teeth of Time as the eons pass and as they retreat laterally a flat bottomed valley with a quiet meandering stream eventually develops where the vertical walled gorge with its plunging cataracts once was.

Thus the geologist recognizes in the Maligne canyon, the canyon of Rocky river, and a hundred other canyons, creations of yesterday, geologically speaking. The cutting of all these gorges began at the close of the Glacial period. The well graded valleys of Pre-glacial times were in many cases obliterated or changed to such an extent by the accumulated deposits of ice transported drift that the streams were compelled to follow new routes. When these newly routed streams were directed by the morainal debris over the wall of an old valley as often happened, a waterfall resulted.

The damming of an old valley sometimes resulted in forcing a stream to abandon entirely the lower part of its Pre-glacial valley. This occurred in the case of Fiddle river, which was forced through a notch in the Ashlar ridge by the blocking of its old valley southeast of Pocahontas. The Fiddle Creek gorge has resulted from this diversion of the stream. The Maligne canyon, 8 miles northeast of Jasper, is the most accessible and best known canyon of the park as well as the most striking example of canyon sculpture in the park. The Maligne river below Medicine lake flows for 8 miles through a valley which is 600 feet or more above the Athabaska river which it joins. Over the lip of the elevated tributary valley the Maligne river descends some 500 feet in less than a mile. This steep

gradient has caused the stream to cut in the upper Devonian limestone which it traverses near the lower end of its valley a deep canyon, with walls, vertical or overhanging and only a few feet apart. Maligne gorge is a splendid example of the carving power of water aided by gravel and boulders. With these simple tools the Maligne river has cut a trench through hard limestone rocks which is nearly 200 feet deep and in places narrow enough for a man to leap across. Gravel banks loaded with boulders, which border the west bank of the stream, have furnished it with the carving tools. Irregularities in the rock bed afford lodging places for boulders and gravel where eddies start them revolving and a rock mill is the result. The sides of the canyon walls, marked with the outlines of long abandoned and partly obliterated wells or pot-holes often 50 feet or more above the present stream, show plainly the process by which it has been carved. In the stream directly above the canyon and in the shallow upper end of it pot-holes are still in process of development, where the sand, gravel and small boulders in shallow pot-like depressions revolving under the force of the current are slowly but steadily grinding away the solid ledges. The gorge in its first stage of development was a string of shallow pot-holes along the bed of the stream, which had not yet entrenched itself in the limestone. In the later stages of its development, a few hundred thousand years hence, Maligne canyon will cut back to and drain Medicine lake.



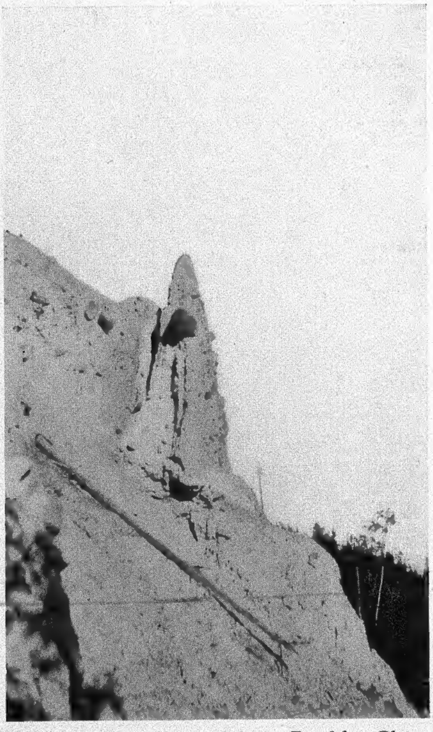
Maligne Canyon.

Kettle Holes, Drumlins and Hoodoos.—The Maligne Lake valley is a district full of interest for the geologist. Perhaps the most unique features in it are those connected in origin with the great Ice Age when the valley was filled nearly to the mountain summits with ice.

Splendid examples of kettle holes—steep sided, deep kettle-like depressions in the glacial drift—occur a few hundred yards northeast of the game warden's cabin near the north end of Maligne lake. These depressions were formed during the retreat of the great valley glaciers and probably represent large buried masses of ice which persisted long enough to give the kettle slope to the mass of sand deposited round them.

On the west side of the lake valley, which near the north end has a width of from one and a half to two miles, curious conical shaped hills are scattered over the valley. These rise like huge bee-hives and are composed of boulder clay, boulders and gravel. These structures are *drumlins*, and are the product of the epoch of great glaciers. Nothing comparable with them is known elsewhere in the park.

The weird clay pillars, which here and there along the trails on mountain slopes arouse the curiosity of the tourist, are also connected with the great valley glaciers of a bygone epoch. The material out of which they are carved represents boulder clay which was part of the ground moraine of a great valley glacier. The boulders are often seen projecting from the sides of the pillars or set on the top like grotesque heads. These ghost-like figures are oddities of erosion produced by the action of rain-water on the sloping margin of a mass of ancient boulder clay.



Hoodoo Pillar Carved from Boulder Clay, Medicine Lake Highway.